WILLIAM MARSH RICE UNIVERSITY

HOUSTON, TEXAS

SEMIANNUAL STATUS REPORT #2

ON

NASA SUSTAINING GRANT NGR-44-006-033

FOR THE DEVELOPMENT OF SPACE SCIENCE AND TECHNOLOGY

FOR THE PERIOD

1 MARCH 1966 THROUGH 31 AUGUST 1966

UNDER THE DIRECTION

OF

ALEXANDER J. DESSLER AND ALAN J. CHAPMAN

INTRODUCTION

The NASA Sustaining Grant for Space Science and Technology, NGR 44-006-033, was awarded in December 1965. The initial grant was backdated to coincide with the academic year starting 1 September 1965. Thus, the grant has not been in force for even a full calendar year; most of the research is still in an undeveloped stage, although significant progress can be reported.

The objective of the Grant is primarily to foster new research in fields of space science and technology at Rice University. Emphasis is given to research carried out by new faculty members, although in a few cases new projects of senior faculty members are being supported. Funds from the Sustaining Grant have also been used for the acquisition of certain items of equipment that serve a general purpose in the areas of space science and technology.

The administration of the grant is carried out under the direction of the Science and Engineering Research Council. This council consists of the following faculty members:

K. S. Pitzer, President

H. E. Rorschach, Professor of Physics, Physics Department, Chairman of Council

A. J. Chapman, Professor of Mechanical Engineering, Department of Mechanical and Aerospace Engineering and Materials Science

A. J. Dessler, Professor of Space Science, Space Science Department

W. E. Gordon, Dean of Science and Engineering

F. Levy, Associate Professor of Economics, Economics Department

C. P. Read, Professor of Biology, Biology Department

Professor A. J. Dessler and Dr. A. J. Chapman have acted as a special subcommittee concerned with this grant.

This grant has had a significant effect in the development of research in space science and technology at Rice in spite of the short time it has been in force. Significant progress in the various projects is certainly expected as the new research programs started by this grant mature.

1. PROJECT: Investigation on the Impact of the Manned Spacecraft Center on the Fiscal Strength of Local Governments in the Surrounding Area

   a. CHIEF INVESTIGATOR: Charles E. McLure, Jr. Assistant Professor of Economics

   b. STATUS REPORT: One of the important effects the Manned Spacecraft Center has had upon the Houston area is its impact upon the fiscal strength of local governments in the area. An analysis is being made of the cost and revenue structures of the Clear Creek Independent School District to determine how the Center has affected the fiscal condition of this local governmental unit. The analysis explicitly considers the Center's effects upon the school district's enrollment, building requirements, tax revenues, and state and federal grants.

2. PROJECT: Investigation on Application of Variational Methods for Determining the Free Boundary of the Impinging Jet

   a. CHIEF INVESTIGATOR: Gary D. Fisher, Assistant Professor of Chemical Engineering

   b. STATUS REPORT: In the impinging jet problem, a jet emerging from a tube impinges perpendicularly against an infinite plane. The boundary of the fluid between the jet exit and the plane is a free boundary in the sense that it is free to assume a position subject to the constraint that the pressure or velocity along the free boundary is constant. The free boundary considerably complicates the problem.

   The flow field for the constant density, inviscid impinging jet was calculated by a potential theory method as adapted to a digital computer. The position of the free boundary was varied until the calculated velocity potential on the boundary was consistent with an assumed free boundary to within an acceptable error. It has been found that the position of the free boundary at any point is a strong function of all other free boundary points.

3. PROJECT: Investigation of the Applicability of the Artificial Viscosity Method to the Solution of Turbulent Boundary Layers

a. CHIEF INVESTIGATOR: W. F. Walker, Assistant Professor of Mechanical Engineering

b. STATUS REPORT: Progress in the investigation has been made according to prior expectations. The first phase of the study has been completed. This included the description of physical and mathematical models to represent the turbulence phenomenon. Modeling of the turbulent shear terms was complicated somewhat by compressibility effects and by the requirement that the model be applicable to configurations other than the conventional flat plate.

The second phase of the investigation (formulation and analysis of the finite difference scheme) has been completed and the resulting system programmed for the IBM 7040. Simple physical problems have been posed and a series of "numerical experiments" performed in order to investigate the numerical stability of the difference equations. These experiments have provided valuable information concerning the stability problems associated with finite difference solutions and have indicated certain approaches by which instabilities can be controlled. At present, these approaches are being explored as is an alternate difference scheme which is believed to have more desirable stability characterisitcs.

4. PROJECT: Investigation of Energy Addition to and Flow Field Studies of the Hypersonic Flow of Partially Ionized Gases through Expansion.

a. CHIEF INVESTIGATOR: F. W. Wierum, Assistant Professor of Mechanical Engineering

b. STATUS REPORT: During the reporting period two projects concerning the energy addition to and flow field studies of the hypersonic flow of partially ionized gases through expansion nozzles have been carried out. One of these projects has been completed, the other is currently nearing completion.

The completed study concerns the spectroscopic study of electron-ion recombination in an Argon plasma. This study is a part of the overall project concerned with establishing the experimental measurements and theoretical assumptions

which are necessary to reliably determine the state of a partially ionized gas as it flows through a converging-diverging nozzle. The results of this research have been reported in a Rice University Ph.D. thesis submitted by M. A. Frost in August, 1966. A paper based on this thesis will be submitted to the Physical Review on October 15, 1966.

The second study is concerned with investigating the use of radio-frequency magnetic fields for adding energy to a supersonic plasma. This research is nearing completion; preliminary data has been collected. These data indicate a faulty group of pressure transducers. These transducers are being replaced by a more reliable group. However, data collection will be delayed until they are installed.

5. PROJECT: An Experimental Study of Standing Sound Waves in Ionized Media

   a. CHIEF INVESTIGATOR: H. K. Beckmann, Professor of Mechanical Engineering

   b. STATUS REPORT: During the report period a suitable method of handling liquid Cesium for use as a working fluid has been developed. The Cesium has been used to create a hot stagnant plasma at about 1/2 atmosphere pressure, using a 4 mc/s induction heater.

   Suitable liquid cooled apparatus has been designed and fabricated so that the very hot plasma can be confined for a reasonable time period. A method of creating standing sound waves in the plasma has been arrived at and is now being readied for test.

6. PROJECT: Investigation of Condensation of Vapors in a Zero-G Environment

   a. CHIEF INVESTIGATOR: A. J. Chapman, Professor of Mechanical Engineering

   b. STATUS REPORT: The analysis of the condensation of a vapor on a horizontal flat surface and the subsequent flow of the liquid film (under the influence of hydrostatic pressure and surface tension) has never been analyzed prior to work done on this grant. This analysis has now been completed, verified by experiment, and extended to the case of condensation of a vapor from a gas-vapor mixture. The work will be extended to cases in which condensation is taking place in the absence of gravity.

A similar analysis has been applied to the problem of free convection about a hot plate facing downward or a cold plate facing upward. This problem has been treated only in an experimental fashion before. Formulas for the prediction of the surface heat transfer coefficient were obtained.

7. PROJECT: Heat Rejection Space Radiator Studies

   a. CHIEF INVESTIGATOR: A. J. Chapman, Professor Mechanical Engineering

   b. STATUS REPORT: The absence of a convective medium means that the only mechanism available for the rejection of waste heat from spacecraft is that of thermal radiation. Currently employed heat rejection systems utilize a bank of finned tubes through which a fluid carrying the internally generated heat flows. At the present time such systems are designed and analyzed by the use of elaborate digital computer programs.

   Work carried out under this grant has been successful in obtaining rather accurate analytical solutions to the following heat rejection radiator problems:

      1. For a given set of conditions (i.e., desired heat rejection and inlet fluid conditions) the necessary size and configuration of the radiator may be analytically determined.

      2. For a given radiator the "known-heat-load" problem (in which a desired heat rejection rate is specified and it is desired to find the requisite inlet and outlet fluid temperatures) has been solved.

      3. The transit response of a radiating fin, subjected to variable heat loads, has been solved.

8. PROJECT: Investigation on Reactions of Atoms with Simple Gases

   a. CHIEF INVESTIGATOR: S. L. Franklin, Professor of Chemistry

   b. STATUS REPORT: This research has been devoted to a study of the effect of benzene upon the nitrogen afterglow. A fast flow reaction system was constructed with facilities for examining radiation by means of filters and photo-multipliers, or, in a few instances, by spectroscopy. The nitrogen

afterglow was produced by passing nitrogen at high flow rates through a microwave discharge. Pressures of about 0.10 to 10 torr were employed. Benzene was added as a gas through a jet into the flowing nitrogen stream. Benzene quenches the nitrogen afterglow, the reduction in intensity of the first positive band system being proportional to the benzene added. Addition of benzene also results in the appearance, in rather faint intensity, of the violet and red bands of CN. The intensity is about 2 orders of magnitude less than is observed when acetylene is added to the nitrogen afterglow. After its first appearance, when very small amounts of benzene are added, additional benzene results in rather rapid quenching of the CN bands, as determined by the intensity of the violet band.

It was found that addition of benzene resulted in the formation of ions in the nitrogen afterglow. This was not unexpected, since the ionization potential of benzene is somewhat less than the recombination energy of nitrogen atoms. The ions were detected by rather crude measurements of conductivity between parallel plates approximately 1 square centimeter in area and placed about 1 centimeter apart. The electrical conductivity rose sharply with benzene addition, and tended to saturate with addition of large amounts of benzene, although complete saturation was never achieved. The conductivity was measured about one meter downstream from the point of benzene admission.

9. PROJECT: Investigation on Chemical Reactions of Oriented Molecules

a. CHIEF INVESTIGATOR: Phillip R. Brooks, Assistant Professor Chemistry

b. STATUS REPORT: The reaction $K + CH_3I \rightarrow KI + CH_3$ has been observed at the intersection of a K beam and a beam of oriented CH_3I molecules. The yield of the reaction is measured for potassium attacking the methyl end of the molecule and for potassium attacking the iodine end. The iodine end is found to be more reactive and semiquantitative data interpreted using a crude model indicate that a K = I collision is necessary for reaction to occur. Other types of reactions are being studied.

Publication: P. R. Brooks and E. M. Jones, "Reactive Scattering of K Atoms from Oriented CH_3I Molecules", J.Chem.Phys.(to be published).

10. PROJECT: Research in Atomic Structure

a. CHIEF INVESTIGATORS: J. A. Jordan, Assistant Professor of Physics, and A. C. L. Barnard, Assistant Professor of Physics

b. STATUS REPORT: The high energy atomic beam technique, in which a monoenergetic, high velocity ion beam streams through a thin foil with the result that the beam atoms emerge from the foil in excited states, has been used to study the structure of HeII. The lifetimes of the 4S, 4D, 4F, 5S, 5P, 5D, and 5F states have been determined by a time-of-flight method; the values obtained are in good agreement with calculated values. (These results were reported at the meeting "The Physics of Free Atoms", Berkeley, California 12-14 September, 1966, and will be submitted to the Journal of the Optical Society of America.)

As a result of the lifetimes study, it was found possible to determine the excitation cross-sections for the various orbital angular momentum states in HeII. These values can be related to Coulomb-Born calculations of electron impact excitation. Data has been obtained in the He bombarding energy range from 800 keV to 2700 keV and will be extended to 5000 keV.

The capability of determining the lifetimes of the various orbital angular momentum states makes possible the examination of the Stark Effect in HeII. From the observed changes in the lifetimes of the excited states can be deduced the fine structure splittings between the states. Early results indicate that the splittings in HeII can be determined to within a few percent.

An adjunct to the HeII experiments has been a project to determine the optimum optical systems, both in the visible and the vacuum ultra-violet, for use in the high energy atomic beam experiments. The usual light gathering problems are severely affected by the large Doppler effects and a thorough analysis of those effects is nearly complete and will be submitted to Applied Optics.

11. PROJECT: Investigation of Isotopic Geochemistry and Cosmochemistry

a. CHIEF INVESTIGATOR: J. A. S. Adams, Professor Geology

b. STATUS REPORT: With the funds provided for this project, a number of small subsidiary items have been bought and installed to completely update and modernize the argon mass spectrometer donated by the Humble Oil and Refining Company. Mechanical vacuum pumps and a mercury diffusion pump have been replaced by a Vacsorb and titanium sublimation pump, giving us a much cleaner system and much more rapid pump-down time. During this period over one hundred potassium argon age determinations were made in connection with a variety of projects in the Geology Department. These include the dating of structural events in California, dating the Precambriam of West Texas, and detailed geochronology in the tertiary section of East Texas where there is very close stratigraphic control.

Currently, certain troublesome parts of the electronics on the mass spectrometer are being replaced by solid-state electronics. Present plans call for expanding the work into potassium argon dating of certain meteorites that have yielded low apparent ages. One working hypothesis is that the apparent low ages are due to the fact that the potassium content varies widely over short distances in these specimens, and perhaps the potassium analysis was done on low potassium portion of the meteorite, while the argon was done on high potassium portion.

Another very promising line of investigation that arose from this dating of tektonic events, was the possibility that rocks crushed during faulting or during meteor impacts may lose almost all of their radiogenic argon, and hence the potassium argon clock is reset. This is definitely the case for certain mylonites formed along fault planes, and is being investigated to see if rocks crushed by underground nuclear explosion lose all or a significant portion of their radiogenic argon. Present plans call for the careful sampling of a few meteor craters to see if they can be dated in this manner.

12. PROJECT: Study of Transport Phenomena in Very Dense Ionized Gases

a. CHIEF INVESTIGATOR: D. D. Clayton, Associate Professor of Space Science

b. STATUS REPORT: A fundamental investigation of transport phenomena in dense ionized gases has been carried out with Dr. P. B. Shaw. The particular problem of heat conduction by relativistic degenerate electrons is nearly solved, but more work remains to be done on the collective scattering cross-section and the ion mobilities. Dr. Shaw has moved to Penn State University, and the research will be summarized for publication there.

13. PROJECT: Experimental Feasibility Study of Neutron Albedo Experiments as Detectors of Hydrogen in the Surfaces of Planets and Satellites

a. CHIEF INVESTIGATOR: R. C. Haymes, Assistant Professor of Space Science

b. STATUS REPORT: This report covers the period 1 March 1966 - 31 August 1966.

A one-curie Pu-Be neutron source has been ordered for this effort. However, there were many delays in securing the necessary licenses and the source was not received until near the end of the reporting period.

Detectors are ready to begin the planned work. Machine-shop work on the necessary sample-holder will commence in the immediate future.

14. PROJECT: Optical Astronomy Program

a. CHIEF INVESTIGATORS: A. J. Dessler, Professor of Space Science

R. P. Kovar, Assistant Professor Space Science

b. STATUS REPORT: Observational work of the Quasi Stellar Sources will be resumed this fall. UBVRI measurements of these objects are being carried out in conjunction with University of Arizona personnel, using the 28-inch reflector

and UBVRI photometer at the Catalina station. Data acquired during the spring of 1966 was reduced during the summer of 1966 and is now available for interpretation.

Investigations of infrared hydrogen line emission (Paschen, Brackett, etc.) from HII regions has shown that measurements of the intensities of these lines will be of importance in computing accurate reddening corrections as well as enlarging our understanding of the radiative transfer problem of these objects. The expected Paschen and Brackett line intensities expected from NGC 1976 have been calculated. It is shown that some of these infrared lines could be detected from the earth's surface.

15. PROJECT: Analysis of Mariner Data and Construction and Calibration of a Low-Energy Proton Detector

a. CHIEF INVESTIGATOR: H. R. Anderson, Assistant Professor of Space Science

b. STATUS REPORT: We have completed the reduction of the Mariner IV ion chamber data to the form of the measured quantity versus time of reception of the data at Earth. All bad data points have been deleted, leaving the above on magnetic tape in digital computer format. From these data we have computed averages for various periods and power spectral density. These results are now being written up for publication.

In the proton detector project supported under this grant we have demonstrated in laboratory tests that protons with energies as low as 50 keV can be counted by unshielded silicon surface-barrier detectors, and their energy measured. The response to electrons of surface-barrier detectors of various thicknesses has also been measured in the laboratory. Suitable preamplifier and coincidence circuits have been built and tested.

16. PROJECT: Acquisition of Random Equalization-Analyzer System for Existing Vibration Equipment

a. CHIEF INVESTIGATOR: A. J. Dessler, Professor of Space Science

b. STATUS REPORT: The existing vibration testing equipment was acquired without a random-noise capability. It became evident that it would be impossible to do required vibration testing for various satellite and sounding rocket payloads unless noise conditions could be simulated. This equipment consists of an 80 channel manual equalizer and an 80 channel spectrum analyzer with necessary peripheral gear. The manual equalizer is one which may be converted to automatic operation at a later date.

This equipment is for the general use of the experimental program being carried out within the Department of Space Science.

EXPENDITURES FOR THE PERIOD
1 MARCH 1966 THROUGH 31 AUGUST 1966

Salaries	$ 54,743
Materials and Supplies	11,613
Computer Services	3,140
Printing and Reproduction	1,091
Travel	1,448
Equipment:	
Major*	21,546
Minor (cost less than $1,000)	3,337
Overhead @ 20%	19,384
Total Expended This Period	116,302
Commitments	65,752
Total Expended to 28 February 1966	24,039
Unexpended Balance	193,907
Total Grant	$ 400,000

*Major Equipment:

MB Model T-486-80 Mixed filter Manual equalized with mixed filters, installed in Rice Space Science Facilities present vibration system with the following additional equipment:

1 ea N166 XY recorder	
1 ea Cabinet Section	
1 ea N165 Logarittimec Convertes	
1 ea N122 true RMC voltmeter	$21,546.50